

Application of Greedy Algorithm in Power Network Wiring

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Abstract: With the continuous development of power systems, the complexity of power network wiring has significantly increased. Optimizing the wiring of power networks while meeting power demands and reliability requirements has become a crucial issue. In this study, the model of the power network wiring problem is simplified and abstracted into the shortest - path problem in graph theory. The greedy algorithm is used to find the optimal layout. The specific steps are as follows: define the node set, edge set, and objective function, and set connectivity constraints and stability constraints to ensure that the constructed power network can not only connect all nodes but also meet certain load - transfer capabilities and stability requirements. The research data is derived from the constructed typical power network model. Through the simulation and analysis of a typical power network, the effectiveness and practicality of the greedy algorithm in power network planning and construction are verified.

Keywords: Greedy algorithm, Power network, Wiring optimization, Cost minimization, System stability

1. Introduction

The wiring design of power networks is an important task in power system planning. It not only involves power supply stability and safety of the system but also relates to minimizing wiring costs. Traditional wiring optimization methods mostly use exact algorithms, such as dynamic programming [1], integer programming [2][3], etc. However, these methods are computationally complex and require long solution times. In contrast, the greedy algorithm, with its simplicity and high efficiency, has been applied successfully in many practical problems [4][5][6]. As mentioned in literature [7], the greedy algorithm shows unique advantages when solving some complex problems related to resource allocation and path planning. This paper attempts to apply the greedy algorithm to the power network wiring problem, aiming to optimize wiring costs while ensuring network stability. Additionally, with the continuous development of 5G technology, the efficient scheduling of network resources is becoming an important issue, and the optimization of greedy algorithm in the network resource scheduling is expected to play a significant role in enhancing overall system performance.

2. Basic principles of the greedy algorithm

The greedy algorithm is an algorithm that starts from a local optimal solution and obtains a global optimal solution by selecting the current optimal solution step by step. Its basic steps include: starting from the initial state and selecting the currently optimal - looking solution each time. Subsequently, each selection decision is based on a local optimal strategy, and once a choice is made, it cannot be

reversed. Finally, the termination condition is usually that the constraints of the problem are reached or the optimization goal is satisfied.

The key characteristic of the greedy algorithm is that the current selection has little impact on future solutions, and each step can form a local optimal solution to the problem. For example, in the problem of finding the shortest path from a starting point to an end - point, if the greedy criterion of the greedy algorithm is set to select the nearest unvisited node from the current position as the next - step moving direction each time, then at each step of the move, the nearest node is preferentially selected. Although this does not necessarily guarantee that the final path is the globally shortest path, in many cases, it can quickly approach the optimal solution, and often yields satisfactory results under specific problem structures.

3. Modeling of the power network wiring problem

The power network wiring problem can be abstracted as the shortest - path problem in graph theory [8]. The nodes of the power network represent substations or power load points, the edges represent power lines, and the goal of wiring is to connect these nodes and minimize the wiring cost.

3.1. Problem description

Consider a power grid system comprising n nodes and m edges. The n nodes here cover various types of substations and power load points. They are distributed in different geographical locations and jointly form the topological structure of the power grid. The m edges represent the possible ways of electrical wire connections. Each edge is assigned a certain wiring cost. This cost is a quantified value obtained by comprehensively considering multiple factors, which reflects the resource investment required for laying electrical wires on that edge. The specific goal of this problem is to select some edges from these m edges to construct a power grid that can connect all n nodes. Moreover, the total wiring cost t of this power grid needs to be minimized. The total wiring cost t is the sum of the wiring costs of all the selected edges.

3.2. Modeling process

- Node set: $V=\{v_1, v_2, \dots, v_n\}$: represents each substation or power load node in the power network.
- Edge set: $E=\{(v_i, v_j)\}$ represents power transmission lines, and each line has a wiring cost c_{ij} .
- Objective function: The goal is to minimize the total wiring cost, expressed as: $\min \sum$

$$(v_i, v_j) \in E c_{ij} x_{ij}$$

where $x_{ij}=1$ indicates that the power line (v_i, v_j) is selected, otherwise $x_{ij}=0$.

3.3. Constraints

3.3.1. Connectivity constraint

Ensures that the power network is connected, meaning there is a path connecting all nodes.

3.3.2. Stability constraint

Ensures that the power system after wiring can meet certain load - transfer capabilities and stability requirements. In this modeling, each transmission line is required that the transfer capacity of each line is at least 50 MW.

4. Application of the greedy algorithm in power network wiring

The greedy algorithm can connect the nodes in the power network step by step by selecting the lines with the lowest cost. Specifically, the application steps of the greedy algorithm are as follows:

4.1. Greedy strategy

Initialization:

Consider each node as an independent set.

Edge selection:

Each time, select an edge with the lowest cost to connect the nodes of two different sets currently.

Set merging:

Merge the two sets to which the two nodes connected by the edge belong into one set.

Repetition:

Repeat the selection of the minimum - cost edge until all nodes are connected into a connected graph.

The core idea of this algorithm is similar to the construction process of the minimum - spanning - tree (MST), especially the Kruskal algorithm [8] or the Prim algorithm [9].

4.2. Time complexity of the greedy algorithm

When the greedy algorithm selects each edge, it needs to sort all edges. Therefore, its time complexity is $O(m \log m)$, where m is the number of edges.

5. Experiments and result analysis

To verify the effectiveness of the greedy algorithm in power network wiring, this study constructs a typical power network model and applies the greedy algorithm for wiring optimization. Suppose the power network has 6 nodes and 9 edges, and the wiring costs and transfer capabilities are shown in the following table 1:

Table 1: Power network wiring costs and transfer capabilities table

Edge (Node Pair)	Wiring Cost c_{ij} (yuan/km)	Transfer Capacity(MW)
(1,2)	10	50
(1,3)	15	60
(2,3)	20	40
(2,4)	25	70
(3,4)	30	80
(3,5)	35	90
(4,5)	40	60
(4,6)	45	50
(5,6)	50	80

According to the steps of the greedy algorithm:

5.1. Filter edges that meet the transfer - capacity requirement

First, the edges with a transfer capacity of less than 50 MW are filtered out for they do not meet the minimum transfer - capacity requirement.

The remaining edges after filtering are as follows:

- (1, 2) - Wiring cost 10 yuan/km, a transfer capacity of 50 MW
- (1, 3) - Wiring cost 15 yuan/km, a transfer capacity of 60 MW
- (2, 4) - Wiring cost 25 yuan/km, a transfer capacity of 70 MW
- (3, 4) - Wiring cost 30 yuan/km, a transfer capacity of 80 MW
- (3, 5) - Wiring cost 35 yuan/km, a transfer capacity of 90 MW
- (4, 5) - Wiring cost 40 yuan/km, a transfer capacity of 60 MW
- (4, 6) - Wiring cost 45 yuan/km, a transfer capacity of 50 MW
- (5, 6) - Wiring cost 50 yuan/km, a transfer capacity of 80 MW

5.2. Sort the edge set: sort the edge set in ascending order of wiring costs.

- (1, 2) - Cost 10 yuan/km, a transfer capacity of 50 MW
- (1, 3) - Cost 15 yuan/km, a transfer capacity of 60 MW
- (2, 4) - Cost 25 yuan/km, a transfer capacity of 70 MW
- (3, 4) - Cost 30 yuan/km, a transfer capacity of 80 MW
- (3, 5) - Cost 35 yuan/km, a transfer capacity of 90 MW
- (4, 5) - Cost 40 yuan/km, a transfer capacity of 60 MW
- (4, 6) - Cost 45 yuan/km, a transfer capacity of 50 MW
- (5, 6) - Cost 50 yuan/km, a transfer capacity of 80 MW

5.3. Select edges and merge nodes

Select the edge with the lowest cost from the sorted edges and avoid forming loops (maintain the connectivity of the network) until all nodes are connected.

- Select (1, 2), Cost 10yuan/km, a transfer capacity of 50 MW. Merge nodes 1 and 2into a set {1, 2}.
- Select (1, 3), Cost 15yuan/km, a transfer capacity of 60 MW. Merge nodes 1 and 3 into a set {1, 2, 3}.
- Select (2, 4), Cost 25yuan/km, a transfer capacity of 70 MW. Merge nodes 2 and 4into a set {1, 2, 3, 4}.
- Select (3, 4), Cost 30yuan/km, a transfer capacity of 80 MW. But nodes 3 and 4 are already in the same set, so skip this edge.
- Select (3, 5), Cost 35yuan/km, a transfer capacity of 90 MW. Merge nodes 3 and 5into a set {1, 2, 3, 4, 5}.
- Select (4, 6), Cost 45yuan/km, a transfer capacity of 50 MW. Merge nodes 4 and 6into a set {1, 2, 3, 4, 5, 6}.

5.4. Final results the selected edges are

Final Results:

The selected edges are:

{(1,2),(1,3),(2,4),(3,5),(4,6)}

The total wiring cost:

10+15+25+35+45=130 (yuan/km)

6. Future development directions

With the rapid development of 5G communication technology, the efficient scheduling of network resources has become a crucial challenge. The greedy algorithm has potential application value in this field [10]. In 5G networks, the number of users is large and the service demands are surging. Different application scenarios, such as high - definition video streaming, industrial control, virtual reality, have varying requirements for communication resources.

From a resource allocation perspective, the greedy algorithm can select the current optimal resource allocation scheme each time according to the priorities and real - time requirements of different services. For example, n delay-sensitive applications such as real-time industrial control, high-bandwidth, low-latency resources are prioritized. Conversely, for services with large data volumes but relatively low requirements for latency, the remaining resources are reasonably allocated on the premise of meeting the basic transmission requirements.

Additionally, the greedy algorithm can also play a role in network congestion control. When network congestion occurs, based on the real - time load conditions of the links and the priorities of data packets, the greedy algorithm selects to discard or delay the transmission of some data packets to relieve congestion and ensure the normal communication of critical services. In addition, during the base station layout and signal coverage optimization of 5G networks, the greedy algorithm can be used to gradually select the best base station locations. While minimizing the construction cost of base stations, the signal coverage range and intensity are maximized. Starting from local optimal decisions, a location that can cover the largest number of uncovered areas with the least signal interference is selected each time to deploy the base station until the communication coverage requirements of the entire area are met. Through these applications, the greedy algorithm is expected to provide strong support for the efficient operation of 5G networks, further enhancing network performance and user experience.

7. Conclusion

This paper optimizes the power network wiring problem through the greedy algorithm, successfully minimizing wiring costs on the basis of ensuring network connectivity and transfer capacity. The experimental results show that the greedy algorithm can generate effective solutions in a short time and has high practical application value.

For future improvements, integrating the greedy algorithm with other optimization techniques, such as heuristic or hybrid algorithms, could enhance its performance and further refine wiring optimization strategies.

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